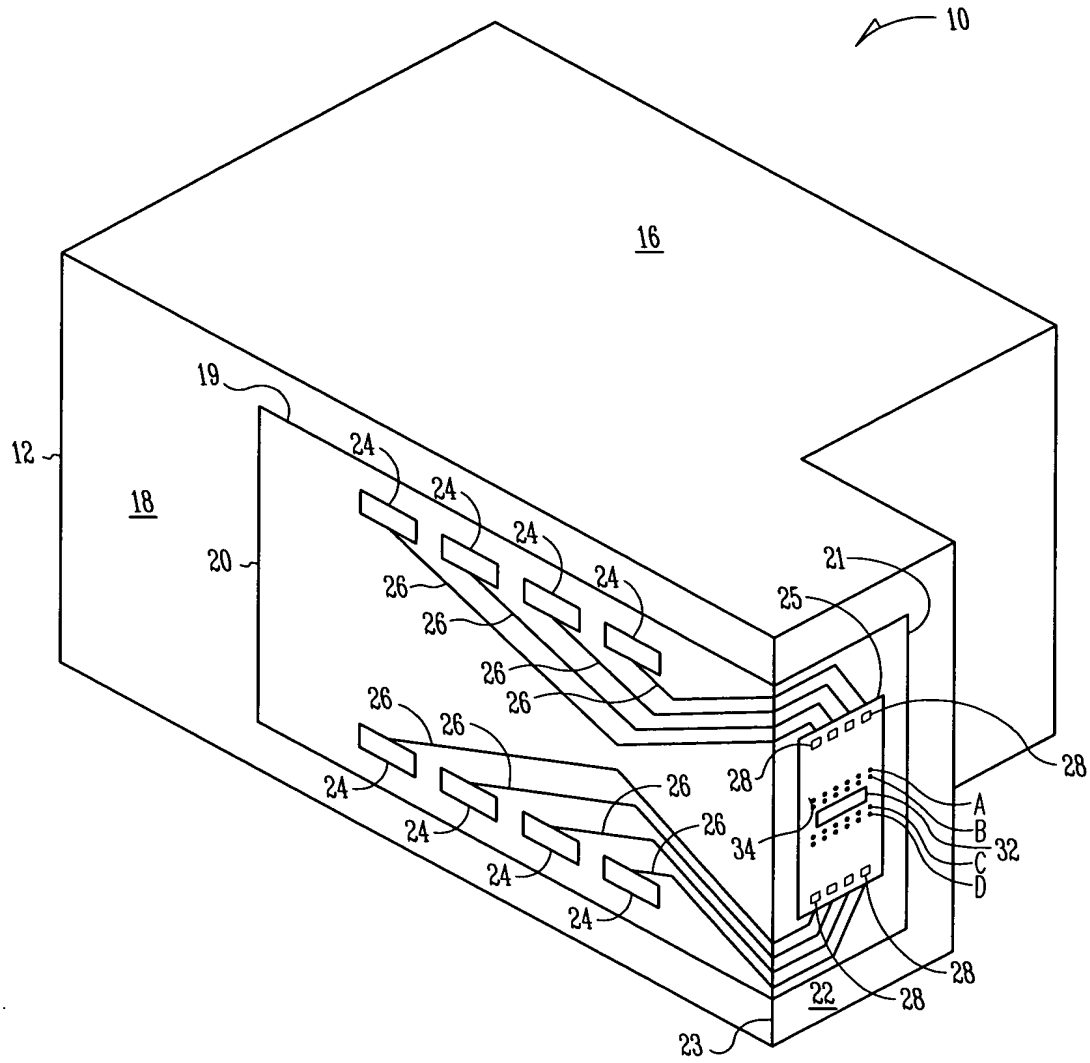

Fig.1

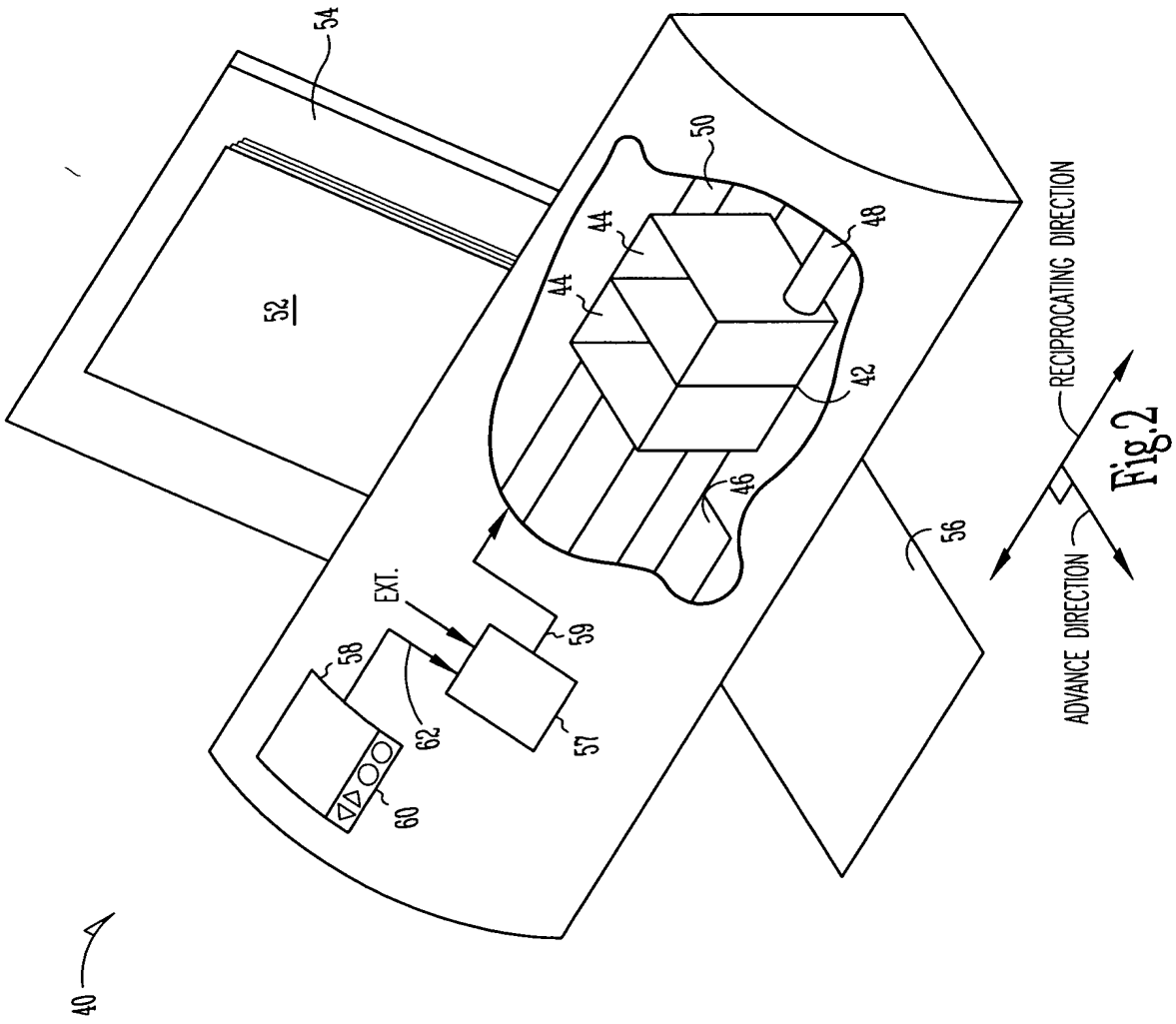
54
52
50
44
44
48
42
46
56
EXT.
58
59
62
57
60
40
RECIPROCATING DIRECTION
ADVANCE DIRECTION

Fig.2

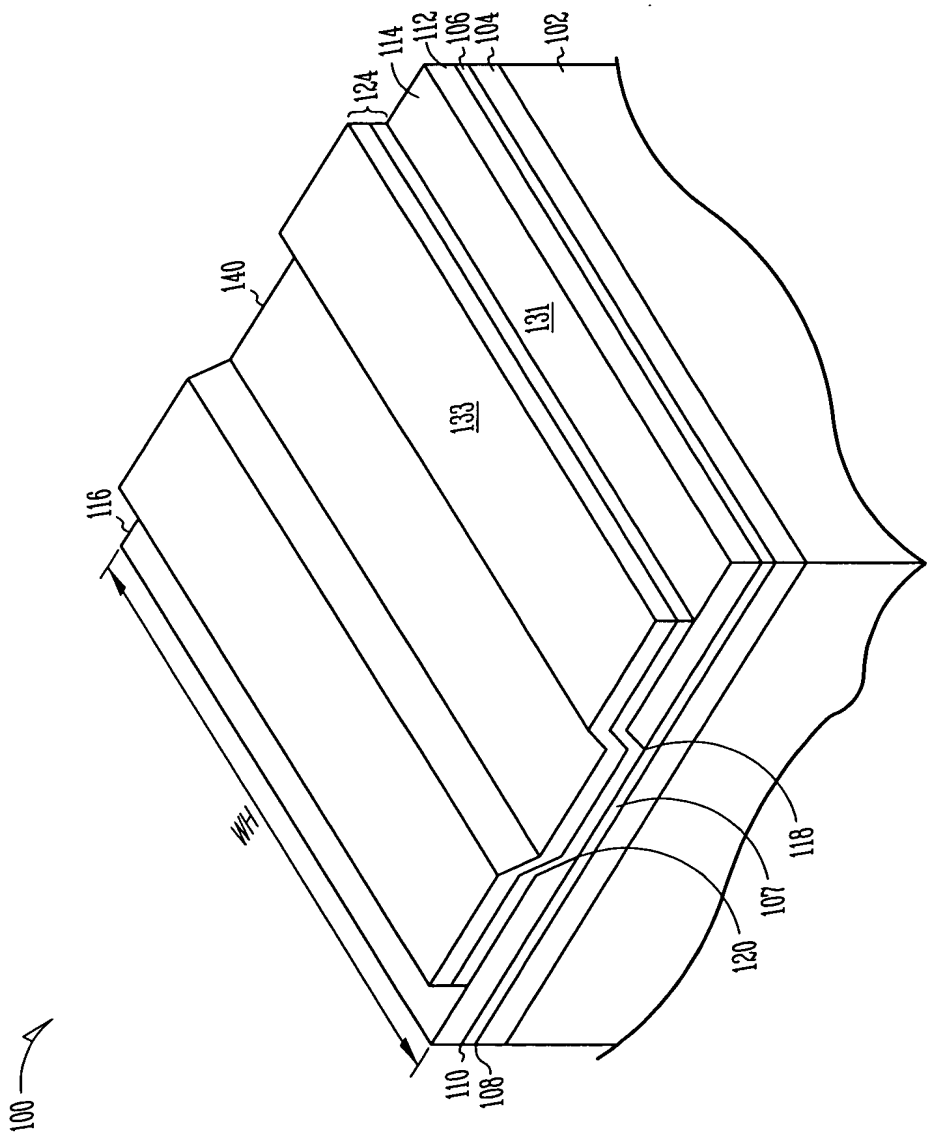
100
102
104
106
112
114
124
140
131
133
116
WH
118
107
120
110
108

Fig.3A

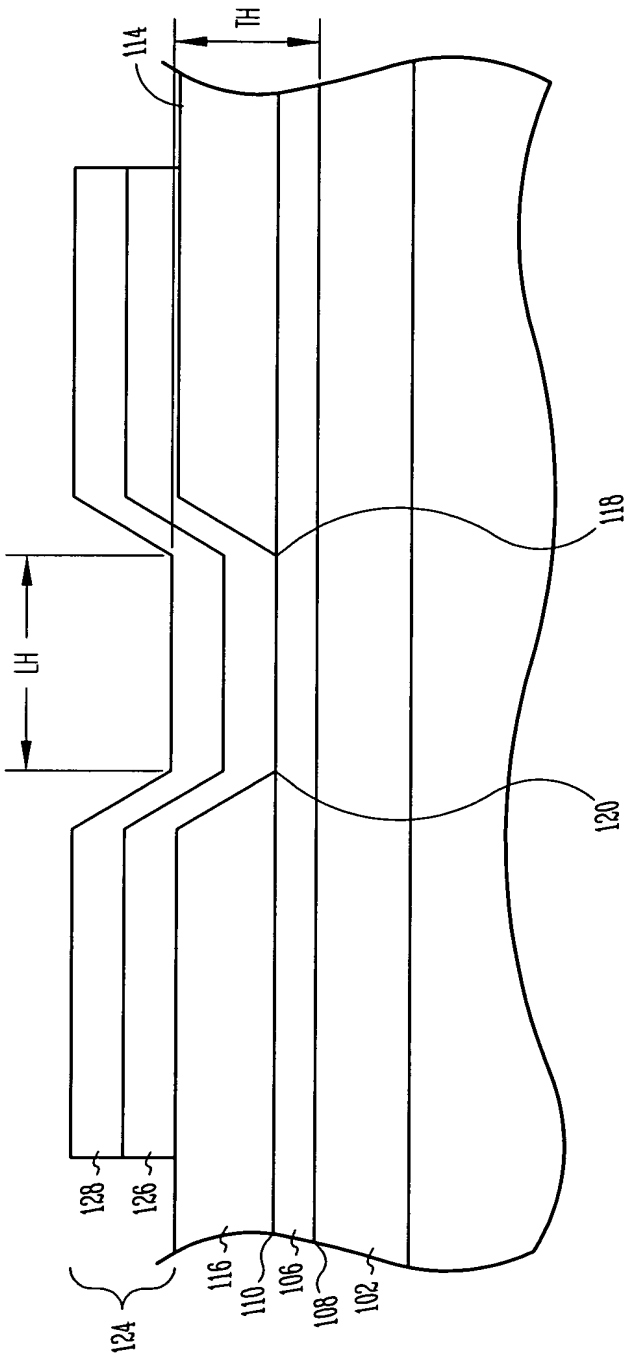

Fig.3B

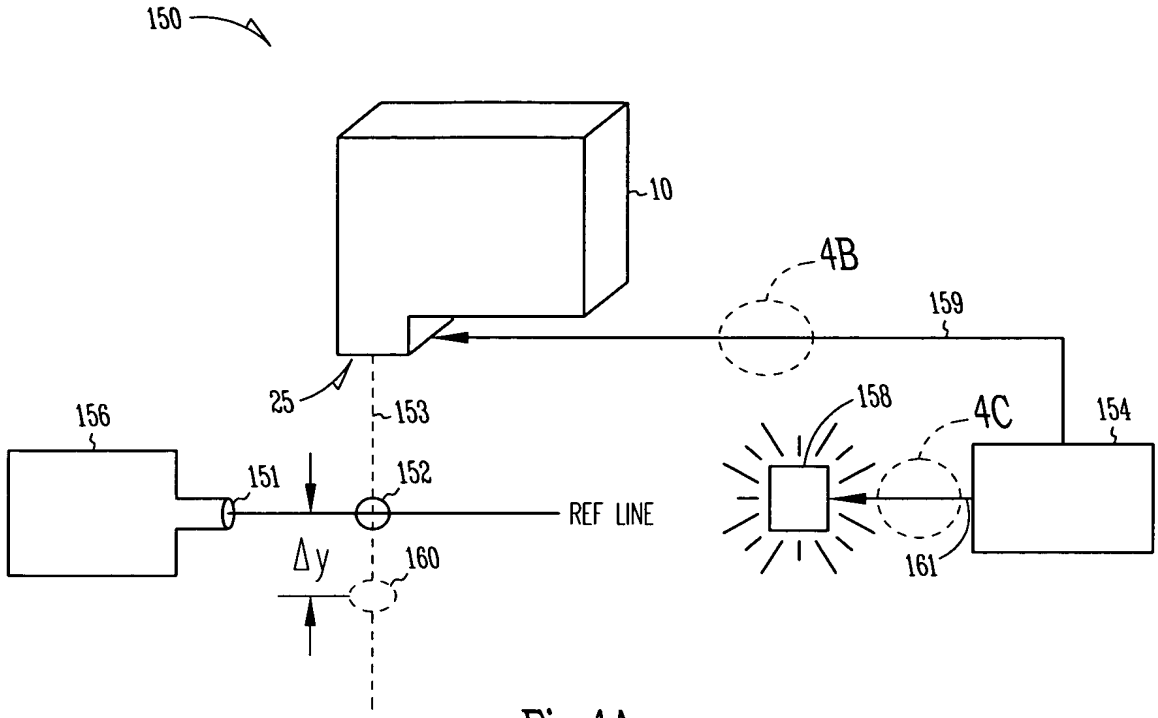

Fig.4A

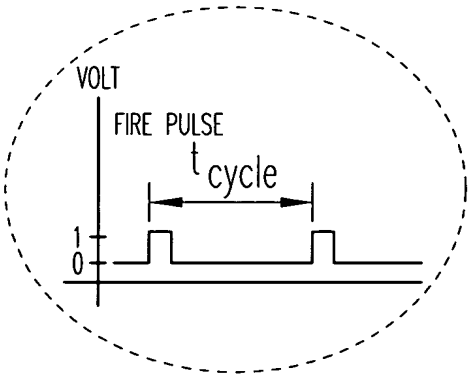

Fig.4B

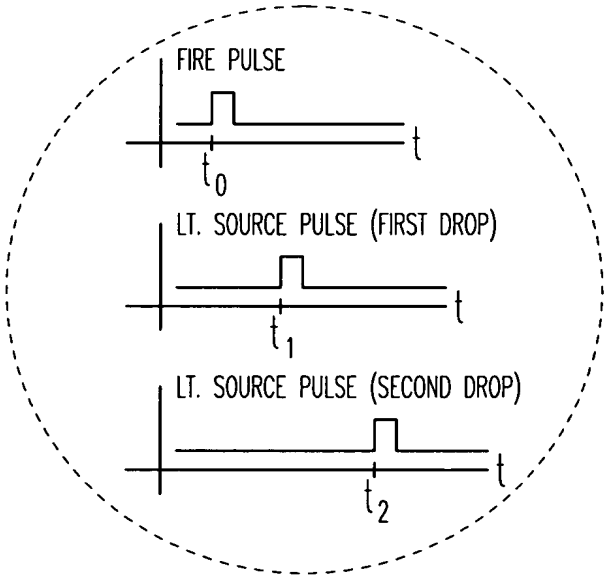

Fig.4C

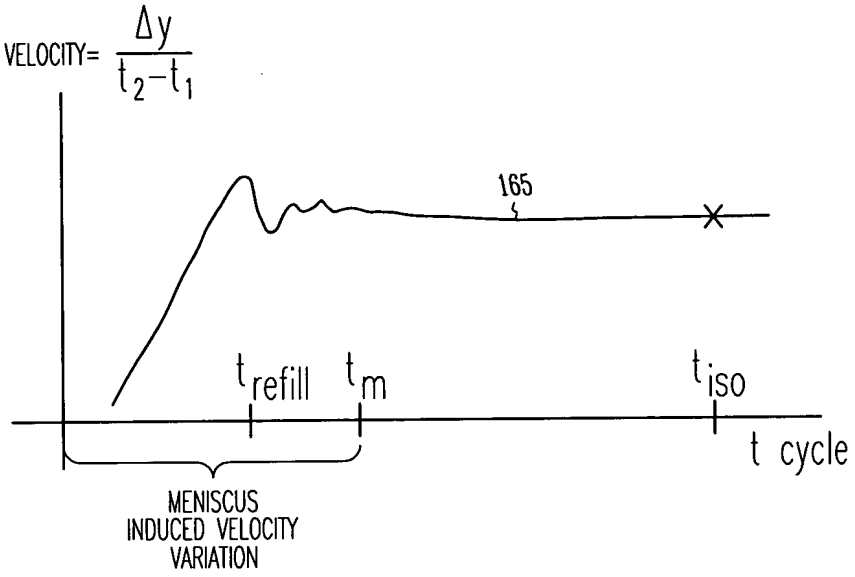
VELOCITY= $\frac{\Delta y}{t_2 - t_1}$
165
t_{refill}
t_m
t_{iso}
t cycle
MENISCUS
INDUCED VELOCITY
VARIATION

Fig.5A

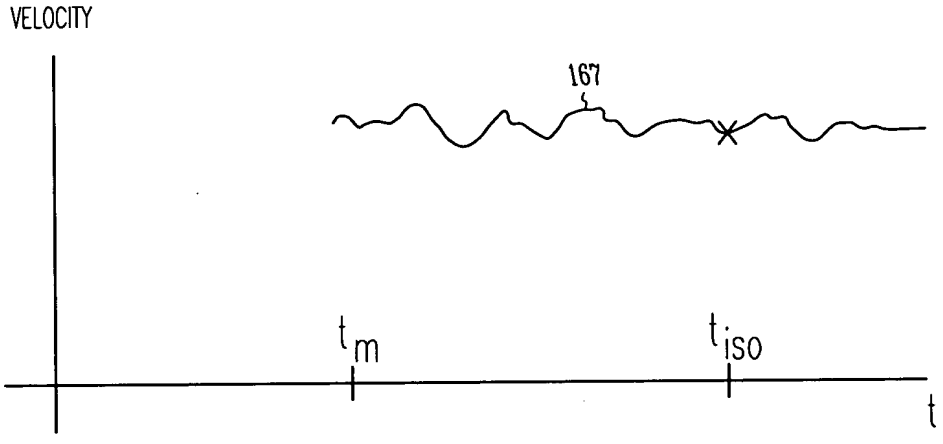
VELOCITY
167
t_m
t_{iso}
t

Fig.5B

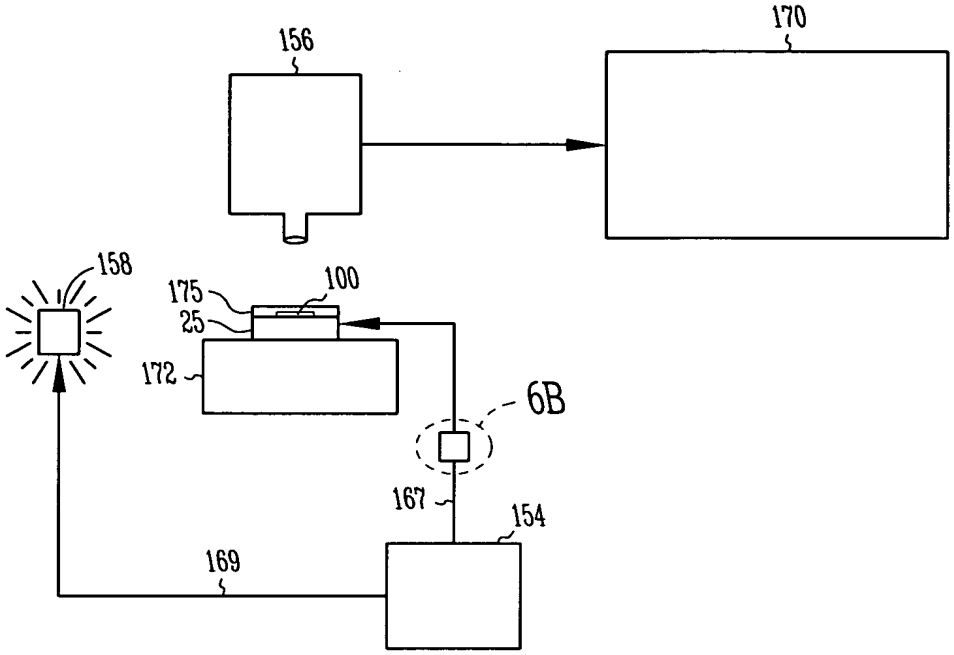

Fig.6A

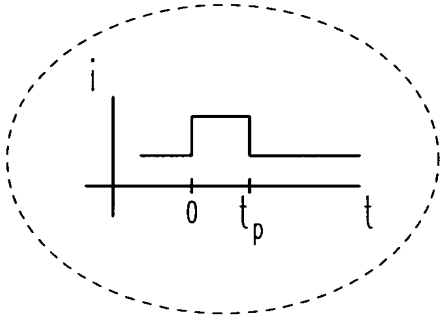

Fig.6B

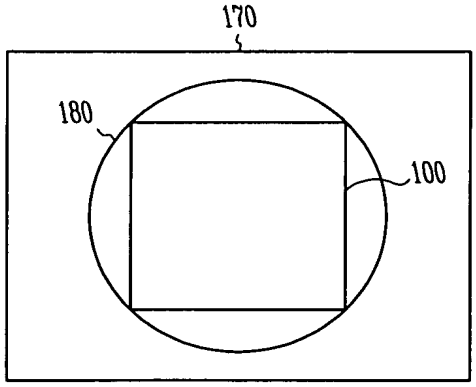

Fig.7A

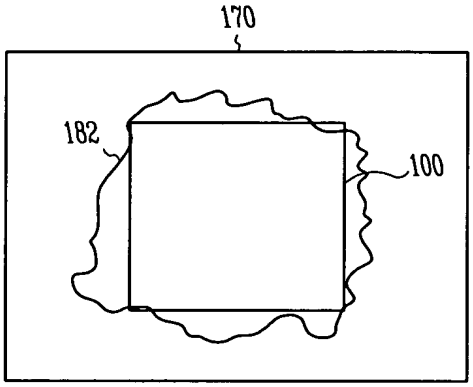

Fig.7B

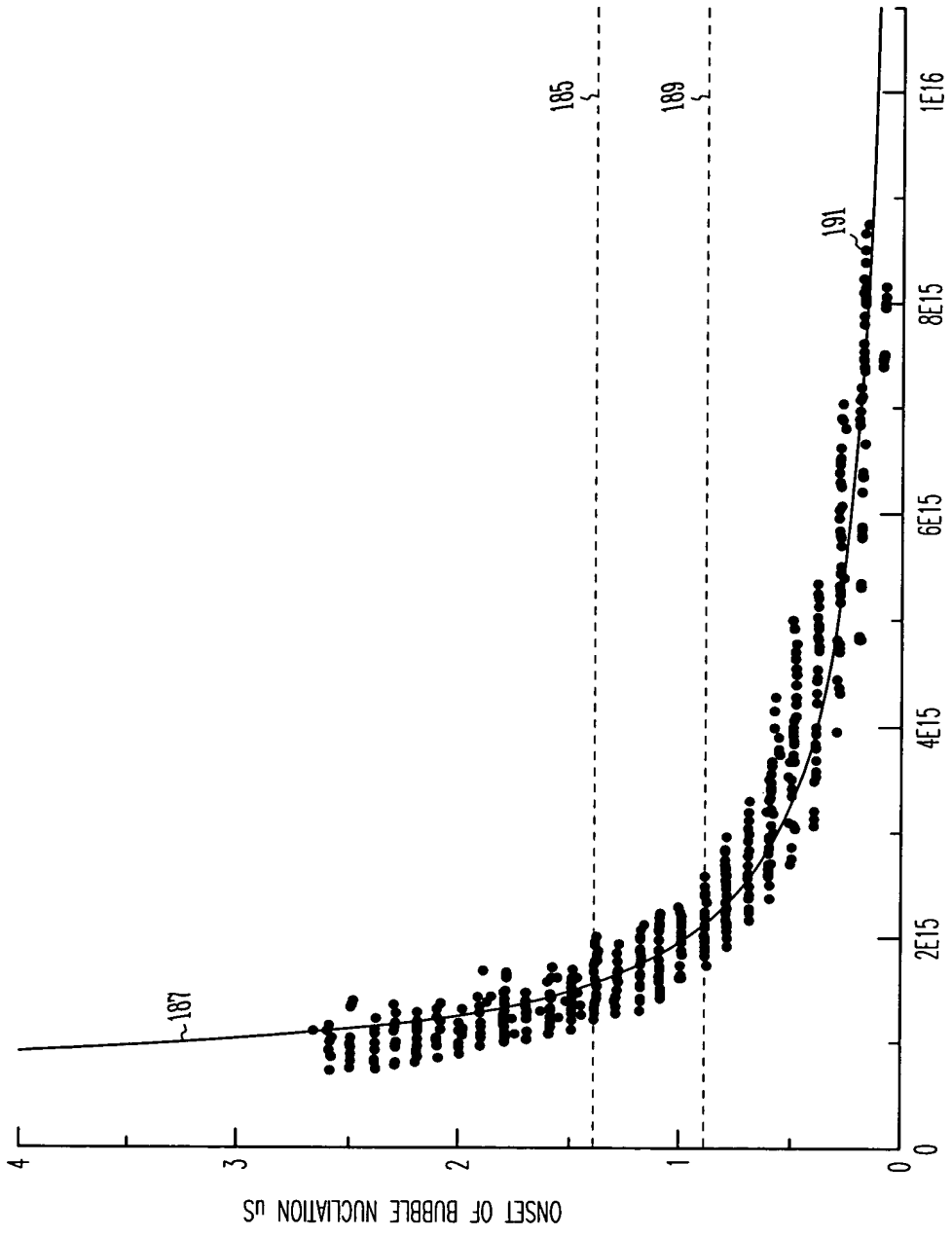
ONSET OF BUBBLE NUCLIATION uS
4
3
2
1
0
187
185
189
191
0
2E15
4E15
6E15
8E15
1E16
HEATER POWER/VOLUME (W/m**3)
(INCLUDES 900 A TaAl)

Fig.8

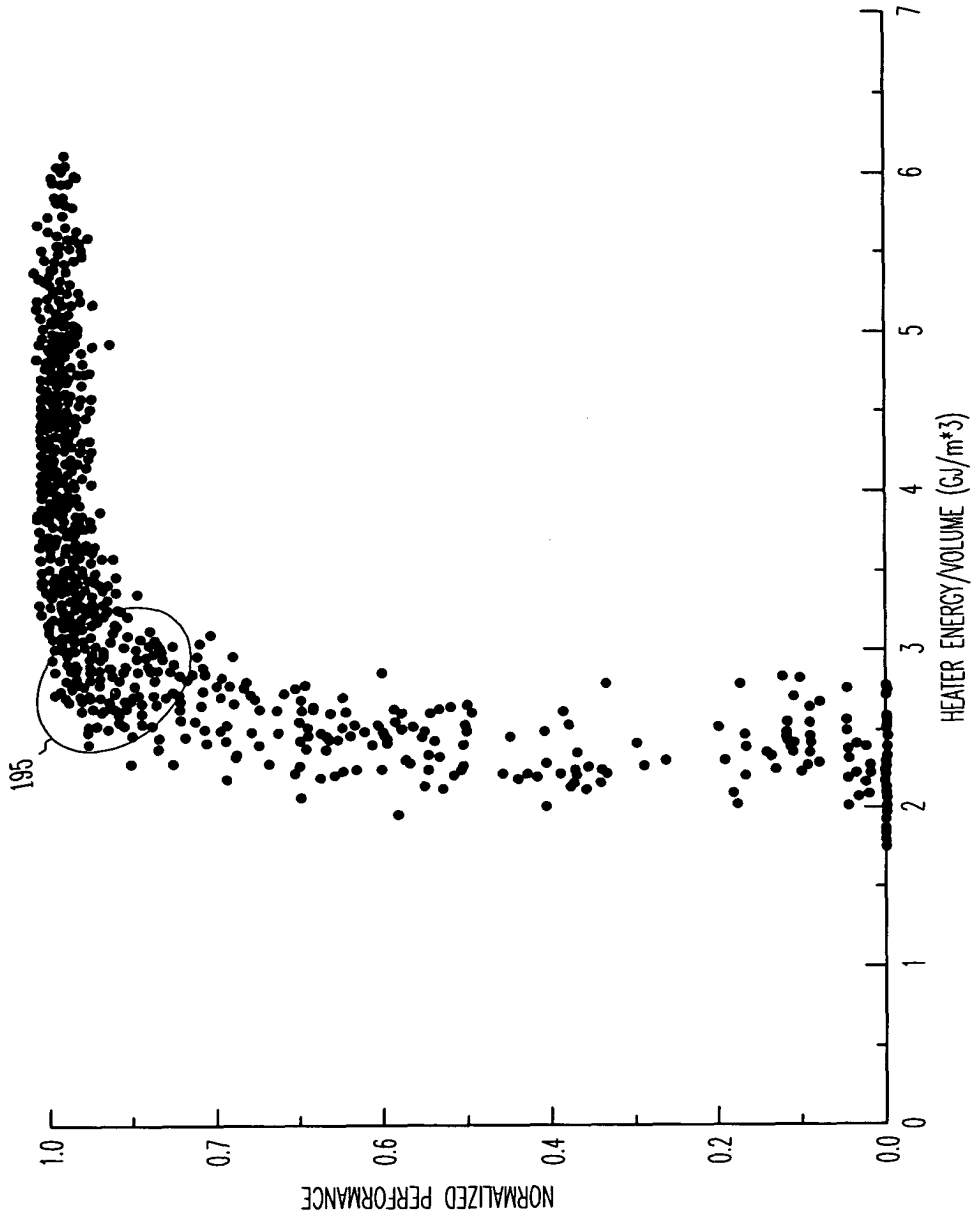
NORMALIZED PERFORMANCE
1.0
0.7
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
HEATER ENERGY/VOLUME (GJ/m*3)
195

Fig.9

ENERGY RANGE (μJOULES) REQUIRED FOR STABLE JETTING PERFORMANCE								
HEATER AREA (μm^2)	HEATER THICKNESS, TH, (ANGSTROMS)							
	1000	2000	3000	4000	5000	6000	7000	8000
50	0.01–0.02	0.03–0.04	0.04–0.06	0.06–0.08	0.07–1.10	0.09–0.12	0.10–0.14	0.12–0.16
100	0.03–0.04	0.06–0.08	0.09–0.12	0.12–0.16	0.15–0.20	0.18–0.24	0.21–0.28	0.24–0.32
150	0.04–0.06	0.09–0.12	0.13–0.18	0.18–0.24	0.22–0.30	0.26–0.36	0.31–0.42	0.35–0.48
200	0.06–0.08	0.12–1.16	0.18–0.24	0.24–0.32	0.29–0.4	0.35–0.48	0.41–0.56	0.47–0.64
250	0.07–0.1	0.15–0.2	0.22–0.3	0.29–0.4	0.37–0.5	0.44–0.6	0.51–0.69	0.59–0.79
300	0.09–0.12	0.18–0.24	0.26–0.36	0.35–0.48	0.44–0.6	0.53–0.71	0.62–0.83	0.71–0.95
350	0.1–0.14	0.21–0.28	0.31–0.42	0.41–0.56	0.51–0.69	0.62–0.83	0.72–0.97	0.82–1.11
400	0.12–0.16	0.24–0.32	0.35–0.48	0.47–0.64	0.59–0.79	0.71–0.95	0.82–1.11	0.94–1.27
450	0.13–0.18	0.26–0.36	0.4–0.54	0.53–0.71	0.66–0.89	0.79–1.07	0.93–1.25	1.06–1.43
500	0.15–0.2	0.29–0.4	0.44–0.6	0.59–0.78	0.74–0.99	0.88–1.19	1.03–1.39	1.18–1.59
550	0.16–0.22	0.32–0.44	0.49–0.66	0.65–0.87	0.81–1.09	0.97–1.31	1.13–1.53	1.29–1.75
600	0.18–0.24	0.35–0.48	0.53–0.71	0.71–0.95	0.88–1.19	1.06–1.43	1.23–1.67	1.41–1.91
650	0.19–0.26	0.38–0.52	0.57–0.77	0.76–1.06	0.96–1.29	1.15–1.55	1.34–1.81	1.53–2.06
700	0.21–0.28	0.41–0.56	0.62–0.83	0.82–1.11	1.03–1.39	1.23–1.67	1.44–1.95	1.65–2.22
750	0.22–0.3	0.44–0.6	0.66–0.89	0.88–1.19	1.1–1.49	1.32–1.79	1.54–2.08	1.76–2.38
800	0.24–0.32	0.47–0.64	0.71–0.95	0.94–1.27	1.18–1.59	1.41–1.91	1.65–2.22	1.88–2.54
850	0.25–0.34	0.5–0.67	0.75–1.01	1.0–1.35	1.25–1.69	1.5–2.02	1.75–2.36	2.0–2.7
900	0.26–0.36	0.53–0.71	0.79–1.07	1.06–1.43	1.32–1.79	1.59–2.14	1.85–2.5	2.12–2.86
950	0.28–0.38	0.56–0.75	0.84–1.13	1.12–1.51	1.4–1.89	1.68–2.26	1.96–2.64	2.23–3.02
1000	0.29–0.4	0.59–0.79	0.88–1.19	1.18–1.59	1.47–1.99	1.76–2.38	2.06–2.78	2.35–3.18
1050	0.31–0.42	0.62–0.83	0.93–1.25	1.23–1.67	1.54–2.08	1.85–2.5	2.16–2.92	2.47–3.33
1100	0.32–0.44	0.65–0.87	0.97–1.31	1.29–1.75	1.62–2.18	1.94–2.62	2.26–3.06	2.59–3.49
1200	0.35–0.48	0.71–0.95	1.06–1.43	1.41–1.91	1.76–2.38	2.12–2.86	2.47–3.33	2.82–3.81
1300	0.38–0.52	0.76–1.03	1.15–1.55	1.53–2.06	1.91–2.58	2.29–3.1	2.68–3.61	3.06–4.13
1400	0.41–0.56	0.82–1.11	1.23–1.67	1.65–2.22	2.06–2.78	2.47–3.33	2.88–3.89	3.29–4.45
1500	0.44–0.6	0.88–1.19	1.32–1.79	1.76–2.38	2.21–2.98	2.65–3.57	3.09–4.17	3.53–4.76
2000	0.59–0.79	1.18–1.59	1.76–2.38	2.35–3.18	2.94–3.97	3.53–4.76	4.12–5.56	4.7–6.35
2500	0.74–0.99	1.47–1.99	2.21–2.98	2.94–3.97	3.68–4.96	4.41–5.96	5.15–6.95	5.88–7.94
3000	0.88–1.19	1.76–2.38	2.65–3.57	3.53–4.76	4.41–5.96	5.29–7.15	6.17–8.34	7.06–9.53
3500	1.03–1.39	2.06–2.78	3.09–4.17	4.12–5.56	5.15–6.95	6.17–8.34	7.2–9.73	8.23–11.1
4000	1.18–1.59	2.35–3.18	3.53–4.76	4.7–6.35	5.88–7.94	7.06–9.53	8.23–11.1	9.41–12.7

Fig.10

ENERGY RANGE (μJOULES) REQUIRED FOR STABLE JETTING PERFORMANCE								
HEATER AREA (μm^2)	HEATER THICKNESS, TH, (ANGSTROMS)							
	9000	10000	11000	12000	13000	14000	15000	16000
50	0.13–0.18	0.15–0.20	.016–0.22	0.18–0.24	0.19–0.26	0.21–0.30	0.22–0.30	0.24–0.32
100	0.26–0.36	0.29–0.40	0.32–0.44	0.35–0.48	0.38–0.48	0.38–0.52	0.44–0.60	0.47–0.64
150	0.40–0.54	0.44–0.60	0.49–0.66	0.53–0.71	0.57–0.77	0.62–0.83	0.66–0.89	0.71–0.95
200	0.53–0.71	0.59–0.79	0.65–0.87	0.71–0.95	0.76–1.03	0.82–1.11	0.88–1.19	0.94–1.27
250	0.66–0.89	0.74–0.99	0.81–1.09	0.88–1.19	0.96–1.29	1.03–1.39	1.1–1.49	1.18–1.59
300	0.79–1.07	0.88–1.19	0.97–1.31	1.06–1.43	1.15–1.55	1.23–1.67	1.32–1.79	1.41–1.91
350	0.93–1.25	1.03–1.39	1.13–1.53	1.23–1.67	1.34–1.81	1.44–1.95	1.54–2.08	1.65–2.22
400	1.06–1.43	1.18–1.59	1.29–1.75	1.41–1.91	1.53–2.06	1.65–2.22	1.76–2.38	1.88–2.54
450	1.19–1.61	1.32–1.79	1.46–1.97	1.59–2.14	1.72–2.32	1.85–2.5	1.98–2.68	2.12–2.86
500	1.32–1.79	1.47–1.99	1.62–2.18	1.76–2.38	1.91–2.58	2.06–2.78	2.21–2.98	2.35–3.18
550	1.46–1.97	1.62–2.18	1.78–2.4	1.94–2.62	2.1–2.84	2.26–3.06	2.43–3.28	2.59–3.49
600	1.59–2.14	1.76–2.38	1.94–2.62	2.12–2.86	2.29–3.1	2.47–3.33	2.65–3.57	2.82–3.81
650	1.72–2.32	1.91–2.58	2.1–2.84	2.29–3.1	2.48–3.35	2.68–3.61	2.87–3.87	3.06–4.13
700	1.85–2.5	2.06–2.78	2.26–3.06	2.47–3.33	2.68–3.61	2.88–3.89	3.09–4.17	3.29–4.45
750	1.98–2.68	2.21–2.98	2.43–3.28	2.65–3.57	2.87–3.87	3.09–4.17	3.31–4.47	3.53–4.76
800	2.12–2.86	2.35–3.18	2.59–3.49	2.82–3.81	3.06–4.13	3.29–4.45	3.53–4.76	3.76–5.08
850	2.25–3.04	2.5–3.37	2.75–3.71	3.0–4.05	3.25–4.39	3.5–4.72	3.75–5.06	4.0–5.4
900	2.38–3.22	2.65–3.57	2.91–3.93	3.18–4.29	3.44–4.64	3.7–5	3.97–5.36	4.23–5.72
950	2.51–3.39	2.79–3.77	3.07–4.15	3.35–4.53	3.63–4.9	3.91–5.28	4.19–5.66	4.47–6.03
1000	2.65–3.57	2.94–3.97	3.23–4.37	3.53–4.76	3.82–5.16	4.12–5.56	4.41–5.96	4.7–6.35
1050	2.78–3.75	3.09–4.17	3.4–4.59	3.7–5.0	4.01–5.42	4.32–5.84	4.63–6.25	4.94–6.67
1100	2.91–3.93	3.23–4.37	3.56–4.8	3.88–5.24	4.2–5.68	4.53–6.11	4.85–6.53	5.17–6.99
1200	3.18–4.29	3.53–4.76	3.88–5.24	4.23–5.72	4.59–6.19	4.94–6.67	5.29–7.15	5.64–7.62
1300	3.44–4.64	3.82–5.16	4.2–5.68	4.59–6.19	4.97–6.71	5.35–7.23	5.73–7.74	6.12–8.26
1400	3.7–5.0	4.12–5.56	4.53–6.11	4.94–6.67	5.35–7.23	5.76–7.78	6.17–8.34	6.59–8.89
1500	3.97–5.36	4.41–5.96	4.85–6.55	5.29–7.15	5.73–7.74	6.17–8.34	6.61–8.93	7.06–9.53
2000	5.29–7.15	5.88–7.94	6.47–8.73	7.06–9.53	7.64–10.3	8.23–11.1	8.82–11.9	9.41–12.7
2500	6.62–8.93	7.35–9.93	8.1–10.9	8.82–11.9	9.6–12.9	10.3–13.9	11.0–14.9	11.8–15.9
3000	7.94–10.7	8.82–11.9	9.7–13.1	10.6–14.3	11.5–15.5	12.4–16.7	13.2–17.9	14.1–19.1
3500	9.3–12.5	10.3–13.9	11.3–15.3	12.4–16.7	13.4–18.1	14.4–19.5	15.4–20.8	16.5–22.2
4000	10.6–14.3	11.8–15.9	12.9–17.5	14.1–19.1	15.3–20.6	16.5–22.2	17.6–23.8	18.8–25.4

Fig.11

ENERGY RANGE (μJOULES) REQUIRED FOR STABLE JETTING PERFORMANCE	
HEATER AREA (μm^2)	HEATER THICKNESS, TH, (ANGSTROMS)
	500
50	0.007–0.01
100	0.01–0.02
150	0.02–0.03
200	0.03–0.04
250	0.04–0.05
300	0.04–0.06
350	0.05–0.07
400	0.06–0.08
450	0.07–0.09
500	0.07–0.10
550	0.08–0.11
600	0.09–0.12
650	0.10–0.13
700	0.10–0.14
750	0.11–0.15
800	0.12–0.16
850	0.12–0.17
900	0.13–0.18
950	0.14–0.19
1000	0.15–0.20
1050	0.15–0.21
1100	0.16–0.22
1200	0.18–0.24
1300	0.19–0.26
1400	0.20–0.27
1500	0.22–0.30
2000	0.29–0.40
2500	0.37–0.50
3000	0.44–0.60
3500	0.51–0.69
4000	0.59–0.79

200

Fig.12